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ENDOPHYLLUM-LIKE RUSTS OF PORTO RICO

E. W. OLIVE AND H. H. WHETZEL

The writers recently spent a little over two months in Porto Rico, from February 23 to April 26, 1916, collecting and studying mainly the parasitic fungi. A fairly representative lot of rusts were collected from many localities about the Island. Among these were five aecidioid and one peculiar uredinoid form which, after germination studies, we found to be short-cycled and similar to, if not indeed identical with, the *Endophyllums*.

We wish to acknowledge special obligation to Professor J. C. Arthur, not only for determining all our rust collections after our return, and for making many suggestions in the preparation of the systematic portion of this paper, but also for directing our attention, prior to our journey, to certain unsolved problems, in particular to the urgent need of clues in the case of the unconnected aecidia of Porto Rico. For the preparation of the agar-water medium and for many other courtesies we are much indebted to Plant Pathologist E. W. Brandes and Director May of the Federal Experiment Station, as well as to Dean Garwood, Professor C. E. Hunn and others of the Agricultural College at Mayagüez. For laboratory facilities and for other freely tendered assistance we are also under great obligations to Mr. J. A. Stevenson, plant pathologist, and to Director Tower, of the Insular Experiment Station at Rio Piedras. After our return from Porto Rico, most of the hosts of our fungi were determined by Director Britton and others of the New York Botanical Garden; the grass hosts by Professor Hitchcock and Mrs. Chase; the ferns by Miss Slosson, to all of whom we desire to acknowledge our great indebtedness. We wish to express our thanks especially to Mr. Percy Wilson of the staff of the New York Botanical Garden, who for several days so generously placed his wide knowledge of West Indian plants entirely at our disposal.

Arthur's "Uredinales of Porto Rico, based on collections by F. L. Stevens,"¹ which proved so very stimulating in our search, enumerates 10 aecidium-forms, all of which he at that time supposed to be heter-

¹ *Mycologia* 7: 168-196, 227-255, 315-332. 1915; 8: 16-33. 1916.

oecious. The discoveries of Kunkel² in the case of *Caeoma nitens* (Schw.) Burrill and of Fromme,³ in connection with *Aecidium tuberculatum* Ellis and Kellerm., by means of which they proved the teliosporic character of the supposed aecidiospores, also acted as a great stimulus in our work. We tried to a limited extent the agar medium recommended by Kunkel, but, laboring under the rather trying tropical conditions, we came finally to use almost exclusively the water surface method. This method proved very efficient, as well as very simple and easy to manipulate. All our germinations were tested successfully again and again by sowing the spores on the surface of water drops placed on slides which were supported up from the bottom of moist chambers. Inverted Petri dishes, with a little water in the bottom to seal the cover, served admirably for the latter.

In order to secure the best results, the spores must float on the surface of the water, so that their germ-tubes may grow up into the moist air. If, on the other hand, the spores are completely immersed, the tubes then appear much like those from true aeciospores. We found also that by chopping up bits of the host tissue with the sori on them, and putting these so that they were not covered with water but merely wet, much better and more abundant germination of the telia resulted.

When once we became convinced of the short-cycled character of one of these aecidium-like rusts, we became suspicious of all and determined to try out the spore germinations of every aecidioid rust with which we came in contact. Our first successful find was in connection with *Aecidium Wedeliae*, one of the commonest and most widely distributed of Porto Rican rusts. Professor Arthur states⁴ that Dr. Stevens had made the suggestion that the alternate host in this case might be *Cyperus*, bearing *Puccinia canaliculata* (Schw.) Lagerh. However, the very commonness of the *Aecidium*, occurring as it does in all sorts of situations, all over the Island, on the host *Wedelia trilobata*, combined with the comparative rarity of the *Cyperus* hosts bearing *Puccinia canaliculata*, made us at once doubtful as to any possible connection between the two. As stated above, our suspicions were confirmed when trials of the germination of *Aecidium Wedeliae*

² Bull. Torrey Bot. Club 40: 361-366. 1913; 43: 559-569. 1916. Amer. Journ. Botany 1: 34-37. 1914.

³ Bull. Torrey Bot. Club 42: 55-61. 1915.

⁴ L. c., p. 318.

showed that the spores produce at once promycelia and that this form is therefore a short-cycled Endophyllum and not a heteroecious form, as had been thought.

In all, we germinated 13 aecidioid and uredinoid forms, in some cases repeating the experiment several times in order to confirm our earlier observations. In 7 of these, the spores germinated very sparsely and very slowly; resulting at the end of 24–48 hours in a few long, unseptated germ-tubes. We therefore became convinced that in these 7 species (*Aecidium passifloriicola* P. Henn., *A. tubulosum* Pat. & Gaill., *A. Tournesortiae* P. Henn., *A. abscedens* Arth., *A. Borreriae* Pat., *Uredo Trichiliae* Arth. (ined.), and the aecial stage of *Uromyces proëminens* (DC.) Pass.) we were dealing in all probability with true aecia and therefore with long-cycled forms. We secured, in fact, considerable evidence in two of the above cases as to possible alternate hosts; coming to the conclusion that the first species was probably associated with *Puccinia Scleriae* (Paz.) Arthur and the second with *Puccinia substriata* Ellis & Barth. Mr. Stevenson, of the Experiment Station at Rio Piedras, had also come to a similar conclusion in the case of the second—*A. tubulosum* on *Solanum*.

The slow and meager germination of the true aeciospores of the above 7 forms is in marked contrast to that of the spores of the short-cycled rusts described below. In the latter case, in an incredibly short time, 10 or 12 hours or even less, nearly all of the spores germinated. When these spores are floated on the surface of water drops in moist chambers, they push out into the free air a profuse mass of unbranched, septate promycelia (basidia), each bearing the 4 (or in some cases only 2) basidiospores (sporidia). It must be kept in mind, however, in germinating these forms, that a source of error is liable to arise if one is not extremely careful in the floating of the spores. When entirely immersed, they always grow out into long tubes, rarely forming sporidia, and might thus easily be mistaken for ordinary aeciospores.

The germ-tubes vary considerably in length as well as in other characteristics in these Endophyllum-like forms. Sometimes, indeed, even in the same lot of germinations, there is considerable variation, due perhaps to their being grown sometimes in moist air only, sometimes partially in water. Two of the species showed, however, a most remarkable variation, which is, in contrast to the above, apparently not at all environmental. The spores of *Endophyllum Stachytarphetae* and of *E. circumscriptum*, on germinating, produce

only 2 spores to each promycelium, instead of the normal 4 basidiospores. We are as yet uncertain as to the constancy of this character; neither are we yet oriented as to its probable significance.

The general characters and systematic arrangement of the short-cycled rusts which we have found to produce promycelia are described below, under 6 species. These are all considered in our title to be Endophyllum-like, although it will be noted that only 4 of the 6 species are really placed in this genus. The first one described is, in fact, not at all aecidioid, but uredinoid in its fructifications; while the last one of the list, while aecidioid, differs sufficiently from Endophyllum to justify its being placed in a separate genus.

Botryorhiza Whetzel & Olive, gen. nov.

Cycle of development includes only telia.

Pycnia unknown (probably not formed).

Telia subepidermal, erumpent; teliospores thin-walled, oval, one-celled, borne singly on long pedicels; each germinating apically on maturity to produce a promycelium with 4 basidiospores; haustoria botryose, or irregularly branched.

Type species, *Botryorhiza Hippocrateae* Whetzel & Olive, on *Hippocratea volubilis*. The generic name is derived from the fact that this form produces large, botryose haustoria, a character apparently occurring also in certain smuts.⁵

Botryorhiza Hippocrateae Whetzel & Olive, sp. nov.

O. Pycnia wanting (probably not formed).

III. Telia mostly hypophyllous but sometimes amphigenous or caulicolous, generally from a localized mycelium, sometimes from a systemic invasion affecting entire young shoots; localized sori densely crowded in more or less orbicular or irregularly shaped, somewhat hypertrophied pulvinate areas, 1 mm.—1 cm. or more across, the affected areas yellowish when young, when older becoming whitish due to the germination of the spores; in older leaves often killing affected spots, which turn brown, the resultant rounded, swollen dead areas then bearing a striking resemblance to certain insect galls.

Telia pulverulent, erumpent, from a definite, superficial, uredinoid

⁵ Lutman (Some contributions to the life history and cytology of the smuts. Trans. Wis. Acad. Sci. 16: 1191-1244. 1910) has figured botryose haustoria in *Doassansia deformans*. (See his figs. 44, 45.)

hymenium which arises just under the epidermis, without peridium; teliospores uninucleate, borne singly at the end of pedicels which arise from a binucleate mycelium, 13-14 by 18-24 μ , thin-walled, oval, with a rounded apical protuberance, germinating apically at maturity to produce each a long, cross-septate basidium (promycelium) bearing 4 basidiospores (sporidia), similar in shape to the teliospores and 8 by 11-12 μ .

Vegetative mycelium composed of coarse intercellular hyphae, made up of binucleate cells, some of which send large botryose, or irregularly shaped, haustoria into adjacent cells.

ON HIPPOCRATEACEAE:

Hippocratea volubilis L., Porto Rico (W. & O. No. 87, *type*; *figs.* 1, 2).

It would indeed be peculiar if this conspicuous fungus had entirely escaped description. We are, however, unable to find any published matter pertaining to it. It is, perhaps, not so strange that it has escaped inclusion in the rusts. In the collections at the Agricultural Experiment Station at Rio Piedras we found it classed as an insect gall; really quite a logical place for an old specimen, when judged alone from its gross appearance.

As is well known, many tropical rusts are pale and inconspicuous and otherwise quite unlike the yellowish or brownish rusts with which we are familiar in colder climates; further, according to Professor Arthur, "all of the so-called species of *Eriosporangium* and *Argomyces* are white-spored, as well as the uredinia of *Uredinopsis* and many others." And he adds: "I see no reason why this is not a true rust, although a very unusual one."⁶

It is, indeed, quite likely that the coarse mycelial hyphae and the remarkable botryose haustoria will prove to be unusual features among rusts; and that these are characters which are doubtless more prevalent among smuts than among rusts. But, on the other hand, the spores are cut off externally, much as in *Uromyces*, from the ends of protruding hyphae; and, further, the spore-bearing hyphae are always produced in a more or less regular, superficial *hymenial layer*, which arises in hypodermal regions, generally just under the epidermis. The latter are undoubtedly rust characteristics and not those of smuts. It is of considerable interest, indeed, to find in this form characters common to both smuts and rusts, thus adding emphasis to the general

⁶ In letter of October 6, 1916.

belief in a common ancestry and a present near relationship for these two great groups.

Endophyllum circumscriptum (Schw.) Whetzel & Olive, comb. nov.

Aecidium circumscriptum Schw.; Berk. & Curtis, Journ. Phila. Acad. Nat. Sci. II. 2: 283. 1853.

Aecidium Cissi Wint. Hedwigia 23: 168. 1884.

O. Pycnia epiphyllous, few, subepidermal, rarely breaking through the epidermis, about 80–85 μ broad in section.

III. Telia amphigenous but mainly hypophyllous, aecidioid, numerous, crowded, cup-shaped, borne in rounded, somewhat hypertrophied, pulvinate areas; peridium recurved, slit into a few coarse segments; teliospores catenulate, more or less rounded-angular or irregular from pressure, 12–13 by 15–18 μ .

ON VITACEAE:

Cissus sicyoides L., Brazil, Costa Rica, Cuba, Dutch Guiana, Jamaica, Porto Rico, St. Thomas (figs. 3, 4).

Endophyllum Wedeliae (Earle) Whetzel & Olive, comb. nov.

Aecidium Wedeliae Earle, Muhlenbergia 1: 16. 1901.

O. Pycnia probably not formed.

III. Telia mainly hypophyllous, aecidioid, densely clustered, borne in light yellowish areas of somewhat irregular shape; peridia scarcely emergent, evanescent; teliospores catenulate, globoid or more or less angular from pressure, 12–13 by 16–18 μ .

ON COMPOSITAE:

Wedelia trilobata (L.) Hitch. Porto Rico, Jamaica and other West Indian Islands (figs. 13, 14).

This is perhaps the commonest of the Endophyllums growing in Porto Rico. As stated above, it was this very abundance that made us suspicious of any possible connection with *Puccinia canaliculata*, as had been suggested by Stevens.

Endophyllum decoloratum (Schw.) Whetzel & Olive, comb. nov.

Aecidium decoloratum Schw. Berk. & Curtis, Journ. Phila. Acad. Nat. Sci. II. 2: 283. 1853.

Aecidium Clibadii Syd. Ann. Myc. 1: 333. 1903.

O. Pycnia probably not formed.

III. Telia hypophyllous, aecidioid, in rounded or sometimes irregular, more or less numerous areas, 2–7 mm. in diameter; peridia evanescent, sometimes short cylindrical, with incised margin; teliospores catenulate, globoid or more or less angular from pressure, 12–13 by 16–18 μ .

ON COMPOSITAE:

Clibadium arboreum J. D. Smith, Mexico.

Clibadium Donnell-Smithii Coult., Guatemala.

Clibadium erosum (Sw.) DC., Porto Rico (figs. 11, 12).

Clibadium erinamense L. Dutch and French Guiana.

We found this Endophyllum only on the slopes of the eastern mountains of Porto Rico, especially the foothills of El Yunque and El Duque.

Endophyllum Stachytarphetae (Henn.) Whetzel & Olive, comb. nov.

Aecidium Stachytarphetae P. Henn. Hedwigia Beibl. 38: 71. 1899.
O. Pycnia probably not formed.

III. Telia hypophyllous, aecidioid, one to few in number to each leaf, occurring in rounded, or somewhat irregular, rather inconspicuous, pulvinate areas; peridia evanescent; teliospores catenulate, globoid or more or less angular from pressure, 14–15 by 15–25 μ .

ON VERBENACEAE:

Stachytarpheta cayennensis (L. C. Rich.) Vahl (*Valerianodes cayennensis* (L. C. Rich.) Kuntze) Porto Rico, Santo Domingo, Bolivia, Colombia (figs. 5, 6).

Stachytarpheta dichotoma Vahl, Brazil (E. Ule No. 2163.)

According to Professor Arthur, this is the first time this rust has been reported from North America. We found it only at Rio Piedras, in a little valley near the Experiment Station. This, also, was the only locality in which we found the host.

Endophylloides Whetzel & Olive, gen. nov.

Cycle of development includes, so far as is known, only telia.

Pycnia unknown, (probably not formed).

Telia erumpent, the chains of spores adhering to form more or less extended, cylindrical columns, about 2–4 times as long as broad, waxy or horny when dry. Peridium wanting, or at least inconspicuous.

Teliospores catenulate, one-celled, germinating at the apex of the column.

Type species, *Endophylloides portoricensis*, on *Mikania cordifolia*.

This form differs markedly from *Endophyllum* in that the latter is much more aecidium-like, with usually prominent peridium-cup and pulverulent masses of spores. Similarly, while undoubtedly resembling in some respects the type genus of *Dietelia*, *D. verruciformis* P. Henn., yet we regard the absence of an evident peridium and the possession of comparatively long, horny columns of teliospores in *Endophylloides*, in contrast to the strongly developed peridial cells and the globose or subglobose telia in *Dietelia*, as sufficiently distinctive to warrant the formation of the new genus.

***Endophylloides portoricensis* Whetzel & Olive, sp. nov.**

Aecidium expansum Arth. Mycol. 7: 317. 1915 (not *A. expansum* Diet.).

O. Pycnia probably not formed.

III. Telia chiefly hypophyllous, sometimes petiicolous or caulicolous, short-cylindrical, forming more or less waxy or horny columns about $\frac{1}{3}$ mm. in diameter by 0.5–1 mm. long, aecidioid, borne in irregularly shaped areas, 0.5–1 or more cm. in diameter; peridial cells inconspicuous, often collapsed, scarcely forming a continuous peridium; teliospores rounded or oval, 12–15 by 15–20 μ , in long persistent chains, separated from each other by prominent intercalary cells.

ON COMPOSITAE:

Mikania cordifolia (L. f.) Willd., Porto Rico (Whetzel & Olive, No. 83, type, figs. 7–10).

Mikania odoratissima Urban, Porto Rico.

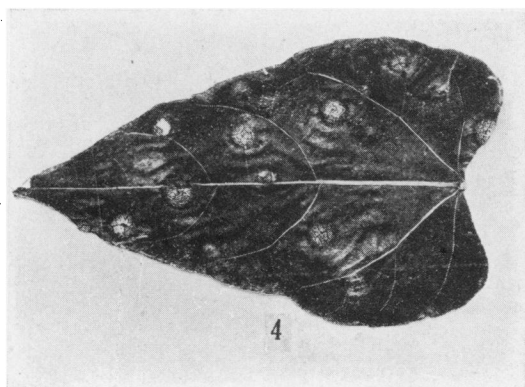
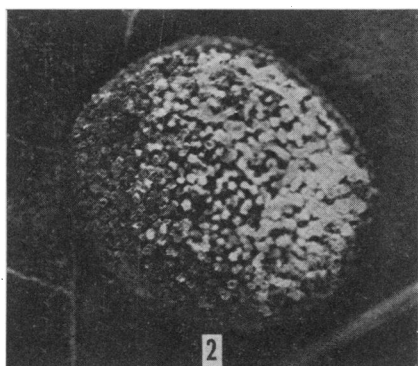
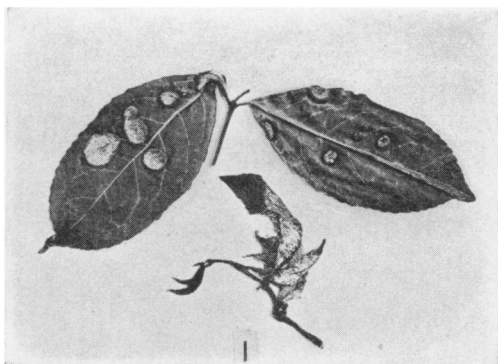
The first host is found very commonly all over the Island, and the fungus is also quite generally distributed. *Mikania odoratissima*, on the other hand, is, in our experience, much rarer. Our collections of the latter were made only on the mountain slopes of El Yunque and El Duque, at the extreme eastern end of the Island.

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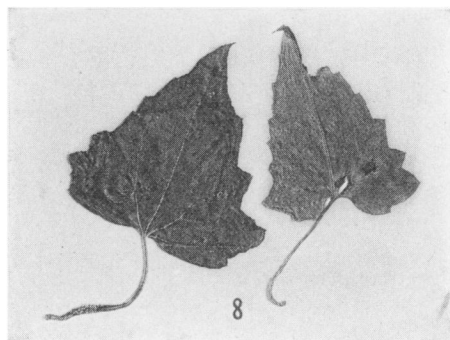
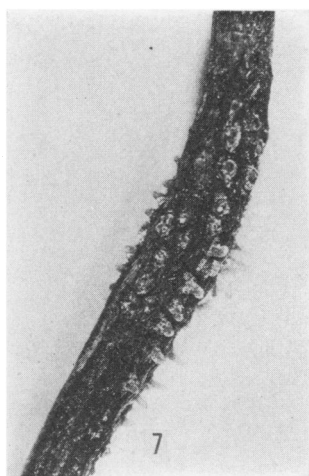
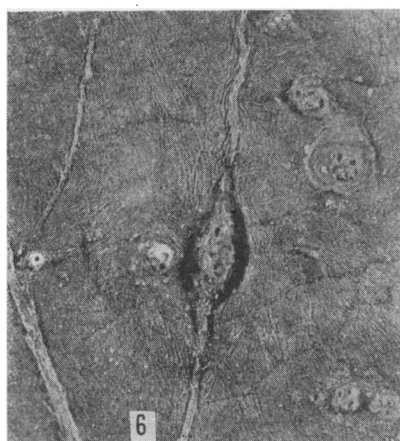
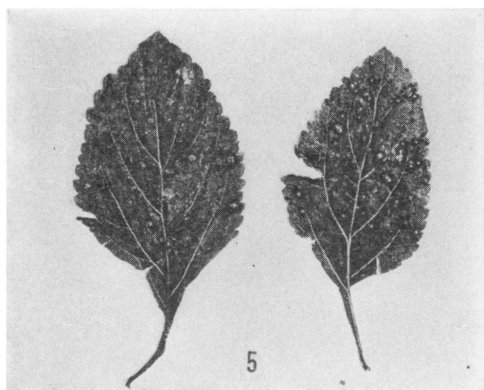
EXPLANATION OF PLATES I-III.

All photos except Fig. 3 were taken by Mr. L. Buhle, of the Brooklyn Botanic Garden. Figure 3 is from a photograph taken in Porto Rico by Prof. Whetzel.

- FIG. 1. *Botryorhiza Hippocrateae*, on leaves of *Hippocratea volubilis*.
FIG. 2. The same, enlarged; \times about 4.
FIG. 3. *Endophyllum circumscriptum*, on leaf of *Cissus sicyoides*; \times about 2.
FIG. 4. The same; \times about $\frac{2}{3}$.
FIG. 5. *Endophyllum Stachytarphetae*, on leaves of *Valerianodes cayennensis*.
FIG. 6. The same, enlarged; \times about 4.
FIG. 7. *Endophylloides portoricensis*, on petiole of leaf of *Mikania odoratissima*; enlarged; \times about 4.
FIG. 8. The same; \times about $\frac{2}{3}$.
FIG. 9. The same, on leaf of *Mikania cordifolia*.
FIG. 10. The same; \times about 3.
FIG. 11. *Endophyllum decoloratum* on leaf of *Clibadium erosum*; \times about $\frac{1}{2}$.
FIG. 12. The same; \times about 3.
FIG. 13. *Endophyllum Wedeliae*, on leaves of *Wedelia trilobata*; \times about $\frac{1}{2}$.
FIG. 14. The same; \times about 3.



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